1955

Welded continuous frames and their components. Lehigh project committee meeting - march 1955

L. S. Beedle

Minutes of the Meeting of the Lehigh Project Subcommittee

March 11, 1955

1. The meeting was called to order at 9:50 with the following members of the committee in attendance: Messrs.: Vasta, MacCutcheon, Howland (representing Newmark), Grover, Higgins, Epstein, Jameson, Weiskopf, Dill, and Beedle. The following were also present: Messrs.: Smith, White, Ketter, Thurlimann, Driscoll, Schutz, and Estes.

2. Reports were presented as shown on the attached Agenda.

3. The status report as of March 11, 1955 was distributed and reviewed. (see attached)

4. The following actions were taken with regard to the topics presented:

Inelastic Instability (205E)

Mr. Vasta expressed an interest in the effective width of a top flange which might be the deck of a ship. This is an item upon which some future studies might be made, particularly in connection with the "built-up members" (248) project.

Procedures of Analysis (205)

Dr. Thurlimann presented a resume of his forthcoming report. It was pointed out that this work differs from previous analytical studies (Brown University, etc.) in that a complete treatment is given for checking the equilibrium condition after the plastic analysis has been carried out. Further a simplification is given for making the mechanism computations for gabled frames (method of instantaneous center).

Connections - Tapered Haunches (205C)

It was agreed that sufficient expression of opinion from the committee had been received and the work on tapered haunch connections -- and curved knees -- could commence. Members of the committee suggested a careful evaluation of the shear stress in haunched connections and also a careful check on the width-thickness ratio of flanges (cross bending). Existing rules should cover these two situations.

Summer Course

The general content and scope of the summer course on plastic design was reviewed and the committee appraised the plans for the September summer school at Lehigh.

Rules of Practice

The committee was advised of the status of expression of opinion by the various committee members. Several specific points on the report were discussed as follows:

1. The committee approved the revised title, "Rules of Practice for Plastic Design in Steel".

2. There was no objection to deleting the word "tentative" from some of the Rules.

3. After a discussion of a figure showing allowable loads according to various specifications and various loading conditions, the committee expressed the opinion that 1.88 should be used as the load factor of safety for bending whenever 1.65 would be used in elastic design. Mr. Weiskopf pointed out that the general philosophy would be to use 1.65 in tension, 1.88 in flexure, and a special factor of safety for compression members (present specifications)

4. For D.L. + L.L. + wind, the factor of safety would be 1.41.

Factor of Safety (205F)

The opinion of the committee was sought with regard to whether or not we should undertake as part of the project a detailed study of the factor of safety. Such a study is not essential to a study of the ultimate strength of structures but is desirable when one is considering the application of plastic analysis to design.

It seemed the consensus of committee opinion was that when the factor of safety was studied it should be done by the group carrying on this work. At least, any other committee (such as ASCE Committee on Factors of Safety) should be completely familiary with the work of the Lehigh Project Subcommittee before undertaking to recommend changes in safety factors. In general, it seems that the committee would go along with substituting a number for the present "1.65" for the time being, but that it might want to undertake a study of the factor of safety in the future.

Special Studies

An outline of the special studies being carried out for course credit without cost to the program was distributed (March 11, 1955).

Column Test Program (205A)

Two proposed changes in the previously-approved program were agreed upon:

(1) Increase the P/P_y ratio for test No. J.

(2) In Series IV (8WF31, weak axis) test Models E, F, and G to be tested under load condition (a) instead of load condition (b).

Reports

It was recommended that abstracts and summaries be included in all project reports (MacCutcheon). With but a few exceptions, this has been done rather consistently.

Lynn S. Beedle

LSB:plt

Distr: Mr. T. R. Higgins (4)
F.L. Project Personnel

A G E N D A

Lehigh Project Subcommittee Meeting
New York, New York
11 March 1955

Morning Session

Preliminary Remarks		9:30
Inelastic Instability (205E)		9:40
Lateral Buckling -- Review of Recent tests	M. W. White	
Local Buckling -- Discussion of report	B. Thurlimann	
Discussion of Further Tests		
Procedures of Analysis (205)		
Presentation of results of analytical work	B. Thurlimann	
Frames (205D)		11:00
Strength of Frames T3 and T4	F. W. Schutz	
Lateral Bracing Requirements (205H)		
Survey of measured forces on various tests		
Lateral Support Systems	J. E. Smith	
Connections (205C)		
Tapered Haunches	J. E. Smith	
Final Action on Proposal	F. W. Schutz	
LUNCH		12:05

Afternoon Session

Summer Course and Conference on Plastic Design in Structural Steel	L. S. Beedle	2:00
Rules of Practice (205)		
Reports for Publication		
Report of Tension Test of Connections	L. S. Beedle	
Report on Frames T1 and T2		
"Plastic Strength of Steel Frames		
Reports on Special Studies		
	L. S. Beedle	
General Status Report and Future Program		
	L. S. Beedle	
Use of Models in Plastic Design (205)		3:15
A demonstration	R. L. Ketter	
Columns (205A)		
Lateral Buckling of Columns - results of analytical work		
Future Program		

Welded Continuous Frames and Their Components

STATUS REPORT

March 11, 1955

This status report is prepared for the semi-annual meeting of the Lehigh Project Subcommittee, Structural Steel Committee, Welding Research Council.

Program Outline

Available to those who wish a copy is a revised PROGRAM OUTLINE, listing the various programs that have been set up as a basis for carrying out the project. The arrangement is according to status of solution ("Current", "Future Planning", "Work Done").

Reports

The following reports have been distributed or published since the last meeting:

10. Closure to "PLASTIC DEFORMATION OF WF BEAM COLUMNS", Ketter, R. L., Kaminsky, E. L., and Beedle, L. S., ASCE Proceedings Separate No. 606, 5/53.

13. Discussion of "STRENGTH OF COLUMNS ELASTICALLY RESTRAINED AND ECCENTRICALLY LOADED", Ketter, R. L. and Beedle, L. S., ASCE Proceedings Separate No. 80, 10/54.

14. "PLASTIC STRENGTH OF STEEL FRAMES", Beedle, L. S., Proceedings, Structural Engineers Association of California, 10/54.

15. "FURTHER TESTS (Tension) OF WELDED CORNER CONNECTIONS", Toprac, A. A. and Beedle, L. S., F.L.Report No. 205C.15. 2/55.

\- "CAN DESIGN BE BASED ON ULTIMATE STRENGTH", Ketter, R.L. and Thurlimann, B., Civil Engineering.

X "LOCAL BUCKLING OF WIDE-FLANGE SHAPES", Haaijer, G. and Thurlimann, B., F. L. Report No. 205E.5, 12/54.

The following reports will be distributed to the Committee or published shortly:

11. "A VIRTUAL DISPLACEMENT METHOD FOR DETERMINING THE STABILITY OF BEAM COLUMNS ABOVE THE ELASTIC LIMIT", Ketter, R. L., (205A.14), 1954.

16. "BEHAVIOR OF WELDED PORTAL FRAMES", Johnston, E. R., Ruzek, J. M., and Beedle, L. S., (205D.2),

17. "BEHAVIOR OF WELDED SINGLE-SPAN FRAMES UNDER COMBINED LOADING", Schilling, C., Schutz, F. W., and Beedle, L. S., (205D.6).

Int-26 "RULES OF PRACTICE FOR PLASTIC DESIGN IN STEEL", Beedle, L. S. and Johnston, B. G., (205.20) (Revised).

Int-27 "ANALYSIS OF FRAMES FOR ULTIMATE STRENGTH", Thurlimann, B.

Other reports are in preparation.

Status

Enclosure 1 lists the projects on which work has been in progress since July 1, 1954, or is planned for the remainder of the year. An indication is given of the nature of work yet to be completed.

Future Plans

Enclosure 2 lists work we are considering for the year 1955-56. Some continuations of studies begun this year and included on enclosure 1 are not repeated. Appropriate specific proposals will be submitted.

Lynn S. Beedle
Assistant Director

205.4
3/9/55

CURRENT WORK '54-55

Enc. 1

	Recently Completed	Current	
	Report	Analysis Tests, Development	Report
Practical Applications			
Evaluation (205-II)	1.P. R. #14 2.Can Design Be Based on Ultimate Strength	--	--
Rules of Practice (205-III)	--	--	Report
Design Examples (205-V)	--	Development	Report
Analysis Procedures (205-VI)	--	--	Report
Use of Models (205-VII)	--	Development	Report
Frame Studies			
Portal-Vertical Load (205D-I)	--	--	Report (16)
Portals-Combined Load (205D-II)	--	--	Report (17)
Arches	--	--	Report (Int-27)
Studies of Components			
Columns:			
Lateral-Torsional Buckling (205A-V)	--	Analysis Tests	Report
Framed Columns (205A-IV)	P. R. #13	--	--
Connections:			
Size Effect (205C-II)	--	--	Report
*Haunched Connections (205C-VI)	--	Analysis Tests	--
"Tension" Behavior (205C-IV)	P. R. #15	Tests (2)	Report
*Built-Up Members (248)	--	Analysis	--
Studies of "Modifications" or "Limitations"			
Inelastic Instability:			
Local Buckling (205E-III)	P. R. X	--	Report (Publ.)
Lateral Buckling (205E-V)	--	Analysis Tests	--
Lateral Bracing Requirements:			
Survey of Measured Forces	--	--	Report
Continuous Structure	--	Analysis Test	--

* Pending final Committee action.

Special Studies by Graduate Students

(Related to but not charged to the project)

Columns-Biaxial Flexure (205A-III)	--	Analysis Tests	--
Beams-Influence of Shear (205B-III)	--	--	Report
Shear Modulus in the Plastic Range (205E-VI)	--	--	Report
Repeated Loading: Deflection Stability (205G-II)	--	--	Report
Box Sections in Plastic Design (247)	--	Analysis Tests	--
Bolted Connections in Plastic Design (245)	--	Analysis Tests	--
Aging (238-I)	--	--	Report

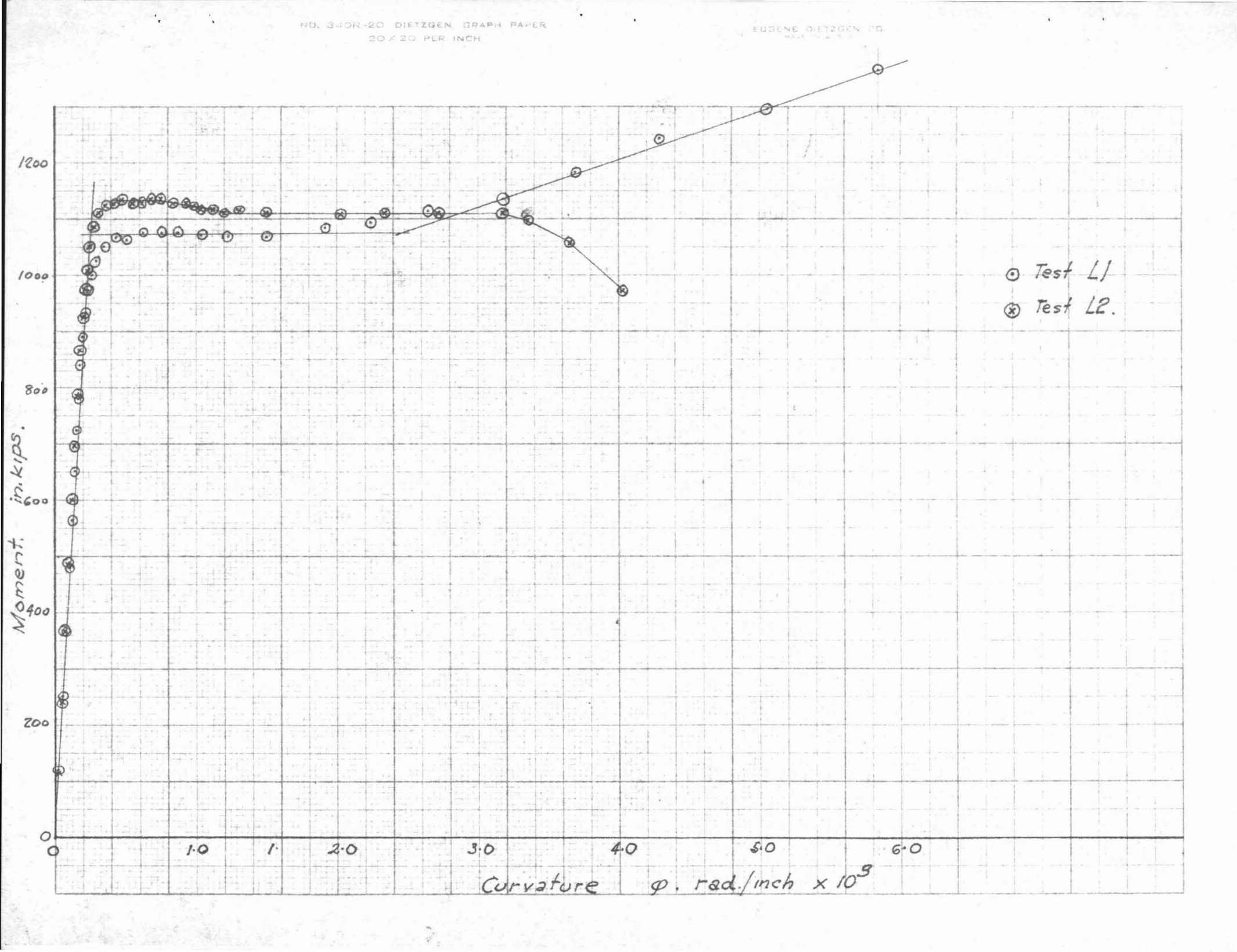
205/FL-119
Rev. 3/8/55

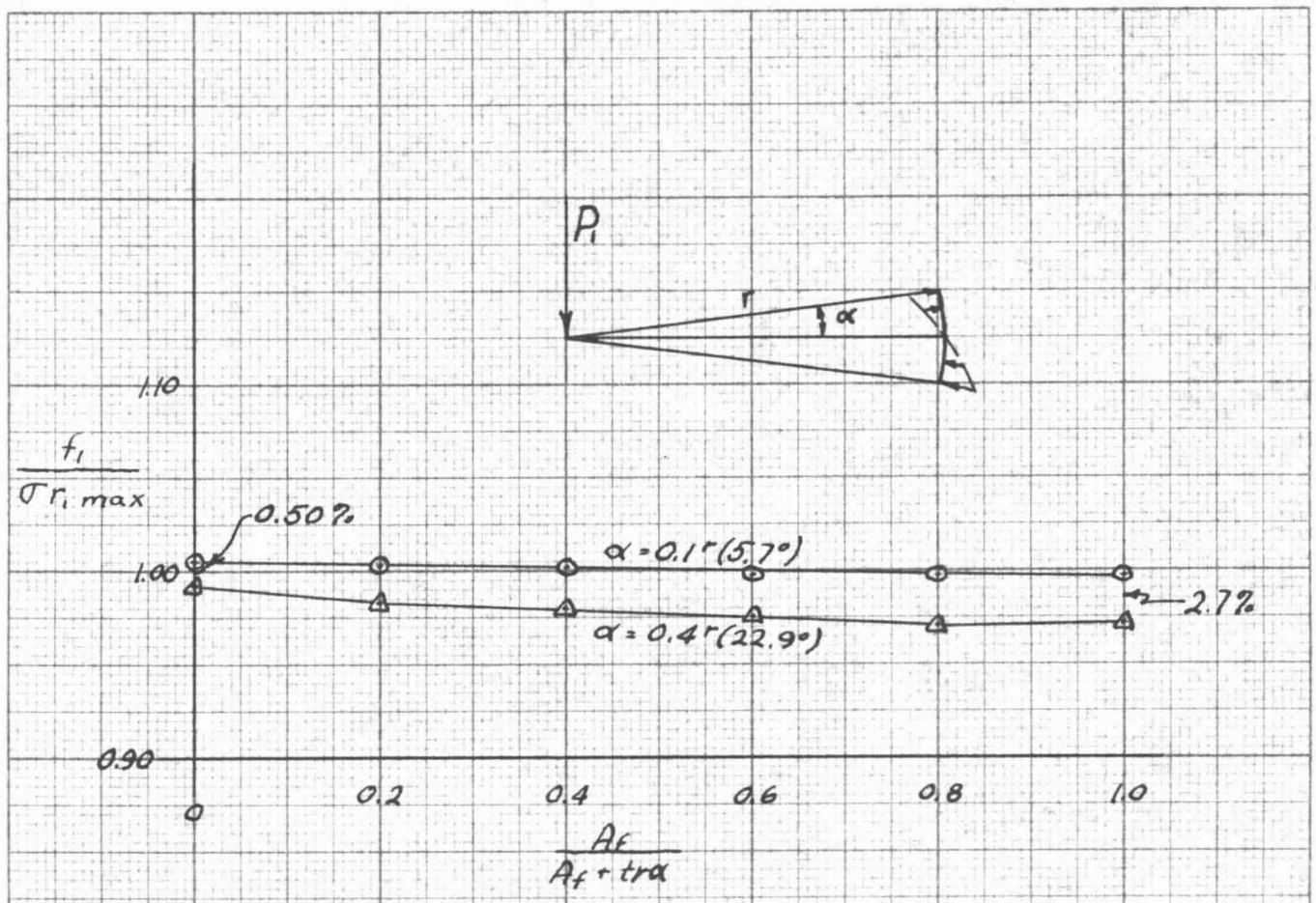
PROGRAM OUTLINE

WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS

PROGRAM	PHASE	CURRENT	Reports	FUTURE PLANNING	WORK DONE	Reports
General (205)	I				(I) Initial Studies	3, 205.18
	II				(II) Evaluation	8, 205.13 12, 14
	III	Rules of Practice in Design	†(26)			
	IV	Tentative Specifications (Portals)		(IV) Tentative Specs. (Tier Bldgs.)		
	V	Design Examples				
	VI	Analysis Procedures				
	VII	Use of Models		(VII) Use of Models		
	VIII			(VIII) Use of I-Shapes		
	IX	Yield Stress Level				
Columns in Continuous Frames (205A)	I				(I) Apparatus and Preliminary Tests	2
	II	Simple Columns with M & P (a, b, d)	6, 10, 11, R		(II) Columns in Single Curvature	10, 11
	III	Biaxial Flexure		(III) Biaxial Flexure		
	IV	Framed Columns	2013.6			
	V	Lateral-Torsional Buckling				
	VI			(VI) Sidesway		
Beams: Static Load (205B)	I				(I) Simple Beams	1.5
	II				(II) Continuous Beams	5
	III	Shear Influence				
Connections (205C) (242)	I				(I) Influence of Design Details	4
	II	Size Effect				
	III	Rotation Capacity				
	IV	"Tension" Behavior	15			
	V			(V) Web reinforcement		
	VI	Haunched Connections (Tapered, Curved, Type 4)				
	VII	Skip-type Knees		(VII) Cold-Temperature Tests		
	VIII			(VIII) Built-up Straight Connections		
	IX			(IX) Encasement		
	X			(X) Miscellaneous Types (Knees)		
Frames (205D)	I	Portals-Vertical Load	7			
	II	Portals-Combined Load	U			
	III			(III) Industrial Frames-2 spans		
	IV			(IV) Tier Buildings		
Inelastic Instability (205E)	I				(I) Compression Tests Coupons	Q, S
	II				(II) Angle Tests	T
	III	WF: Local Buckling {Bending, Direct Compr.}				
	IV	Stiffening				
	V	Lateral Buckling				
Deflections & Factor of Safety (205F)	I				(I) Preliminary Deflection Studies	3, 9
	II			(II) Deflection Limitations		
	III	F.S. Static Load (for load types)				
	IV			(IV) F.S. Repeated Load		
	V			(V) Studies of Loading		
Repeated Loading (205G)	I	Preliminary Studies of Deflection Stability				
	II			(II) Plastic Fatigue {Conns., Beams}		
Lateral Bracing Requirements (205H)	I	Corner Connections	4			
	II	Girders and Beams				
	III	Columns				
	IV			(IV) Encasement		
Box Sections in Plastic Design (247)	I			(I) Corner Connections		
	II			(II) Beams		
Impact (205I)	I			(I) Corner Connections		
	II			(II) Beams		
Built-Up Members (248)	I			(I) Preliminary Survey		
	II			(II) Beams		
	III			(III) Corner Connections*		
	IV			(IV) Columns		
	V			(V) Rules of Practice		
Arches	I			(I) Model Studies		
Bolted Connections in Plastic Design (245)	I	Beams				
Aging (238)	I	Beams - Uniform Moment		(II) Beams - Moment Gradient		
Mechanical Properties (220A)	I	Shear Modulus in the plastic range (241)				
	II	Yield Stress Level				
Miscellaneous Building Connections	I			(I) Beam to Exterior Column		
	II			(II) Beam Continuous over Column		
	III			(III) Peak Connection		
	IV			(IV) Beam to Girder		
	V			(V) Purlin & Girt		
	VI			(VI) Splices		

* Formerly, phases 205C - VII and VIII
† Numbers in parenthesis are Interim Reports, all others are Progress Reports



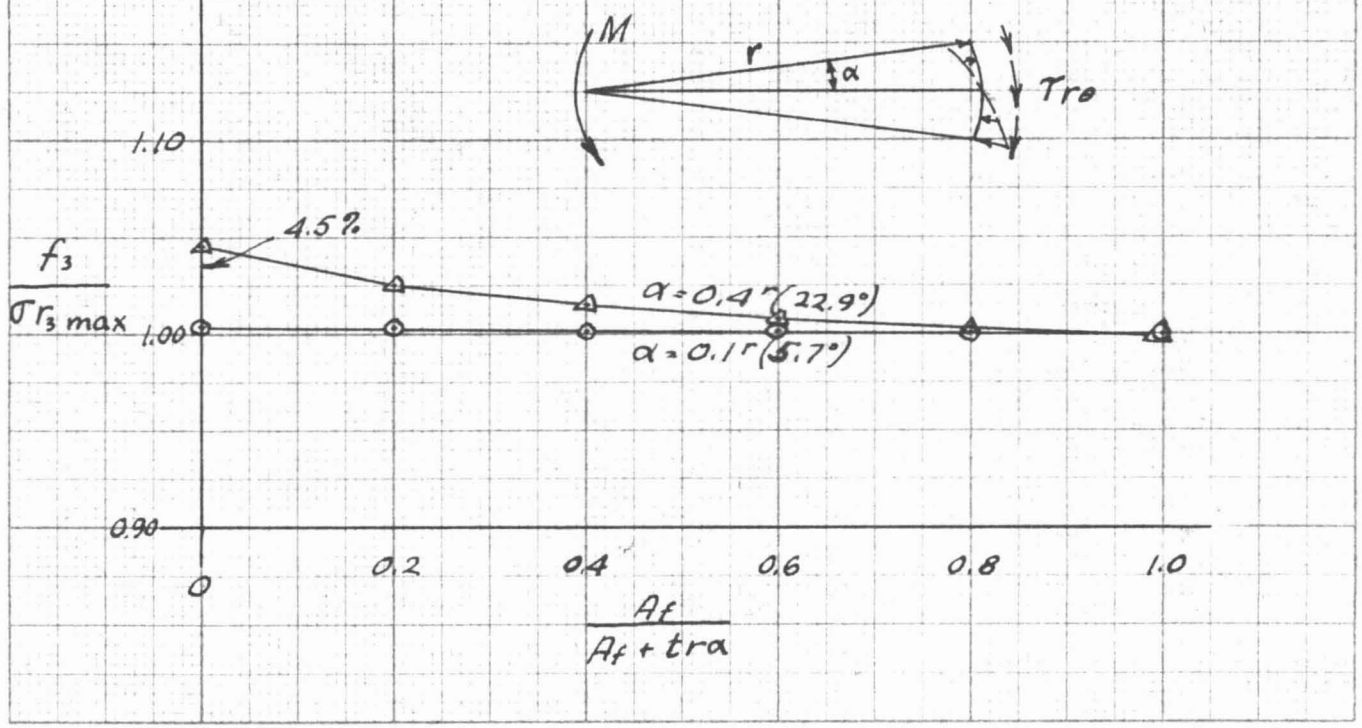


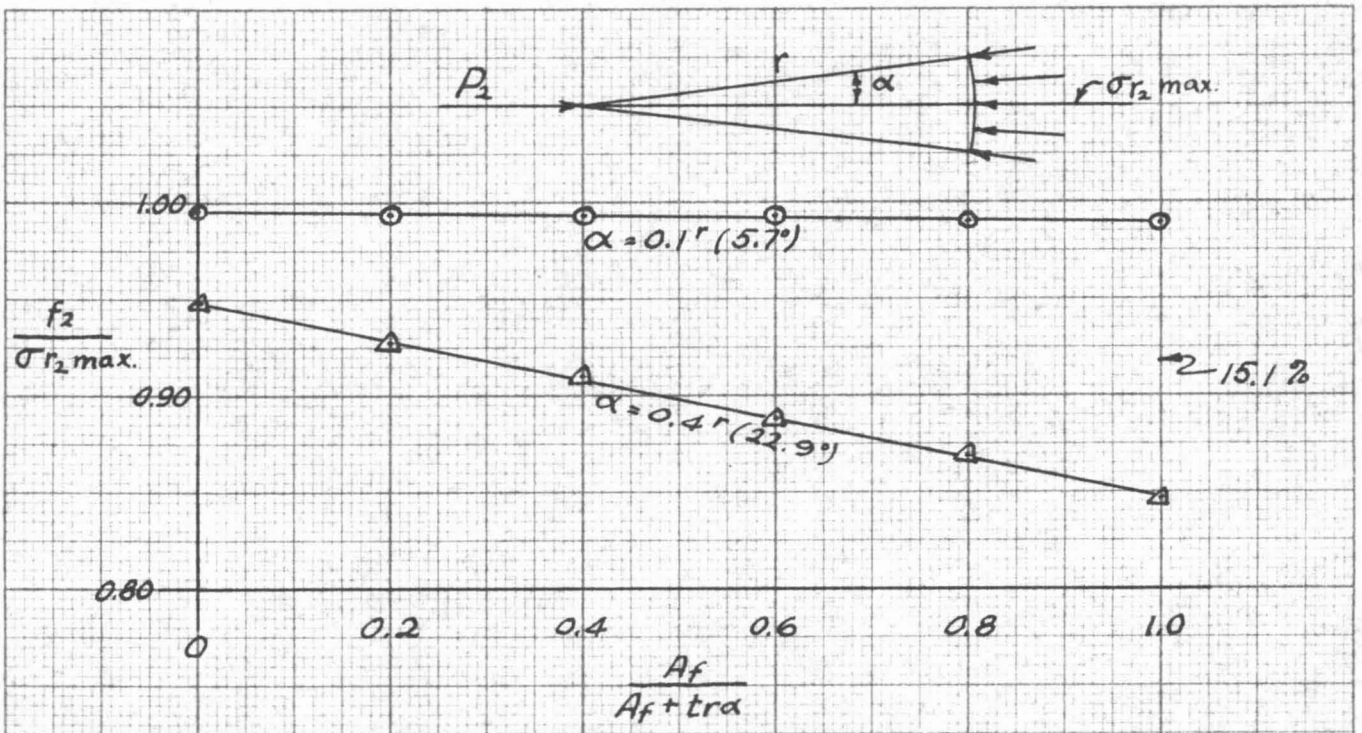
A_f = Area of one flange

$tr\alpha$ = Area of one-half web

f = Stress by simplified method (Olander)

σ = Stress by more rational method (Osgood)





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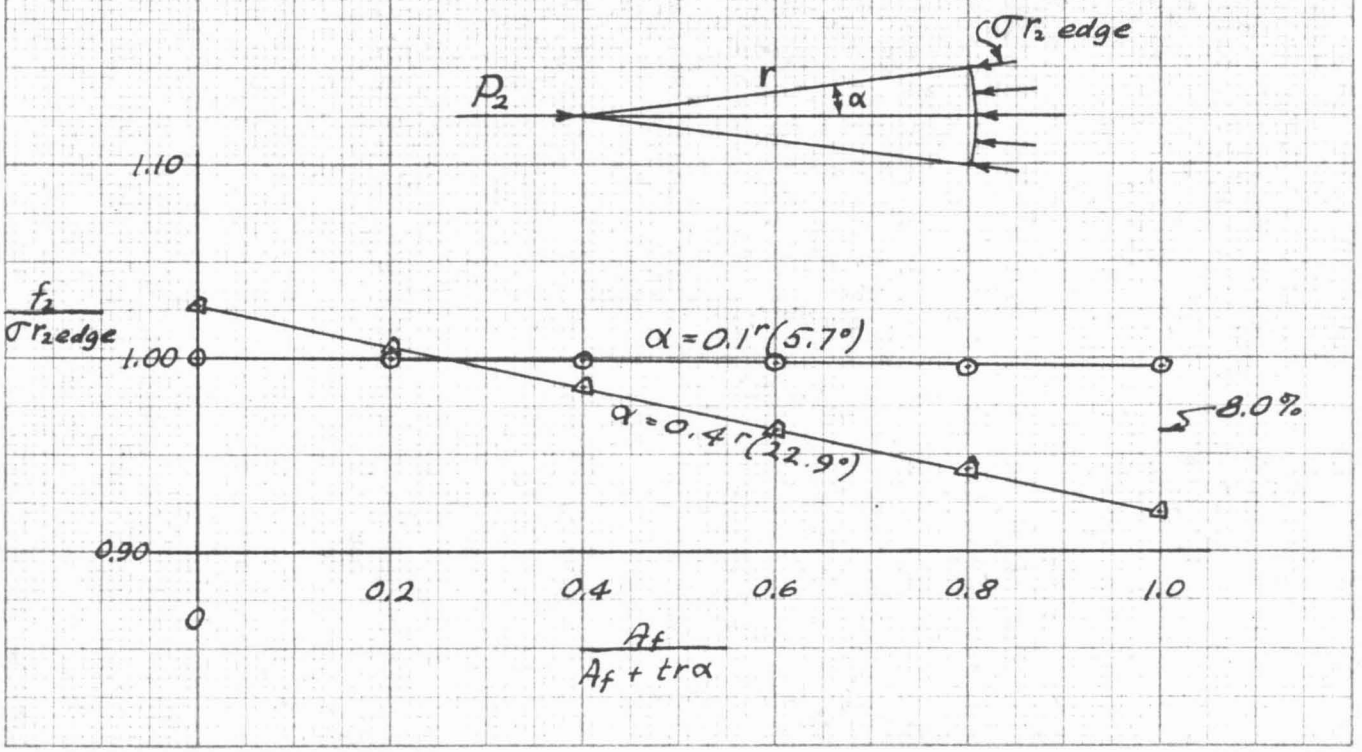
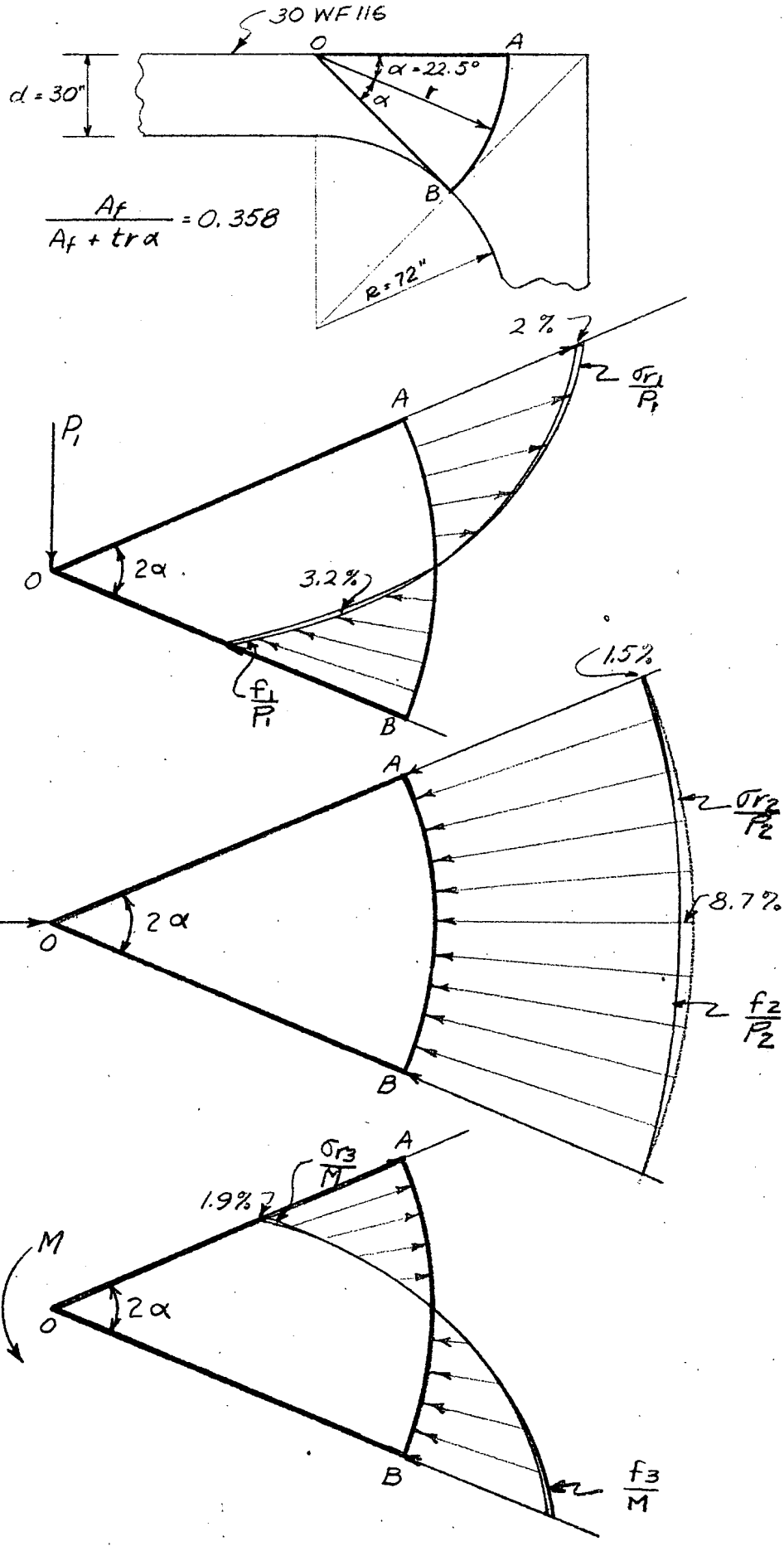
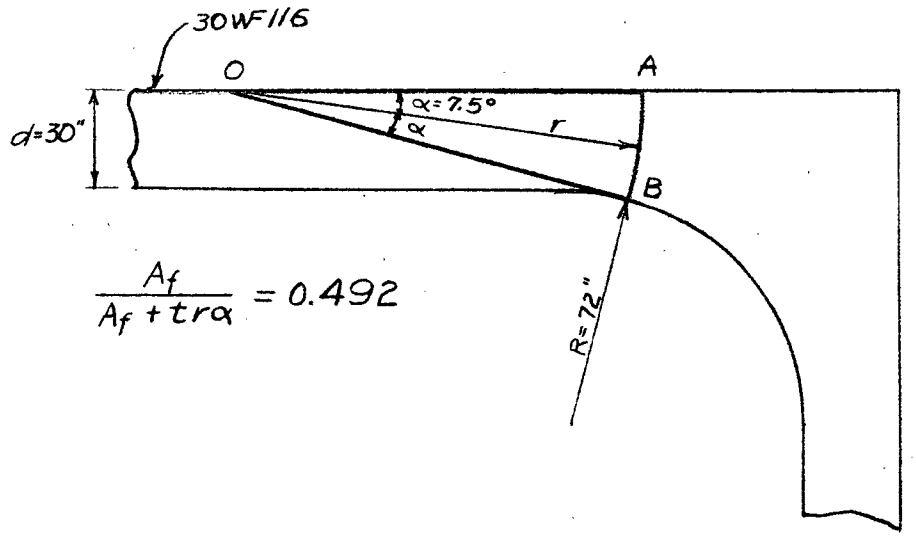
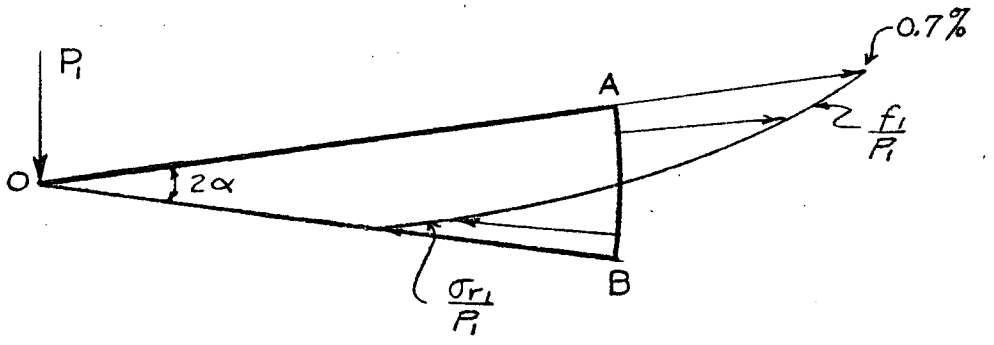
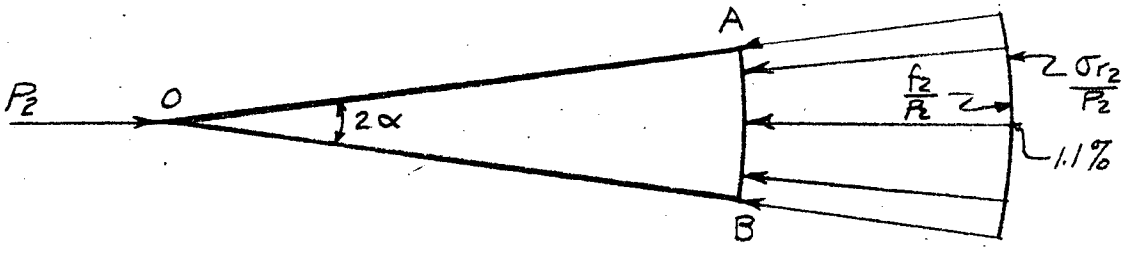


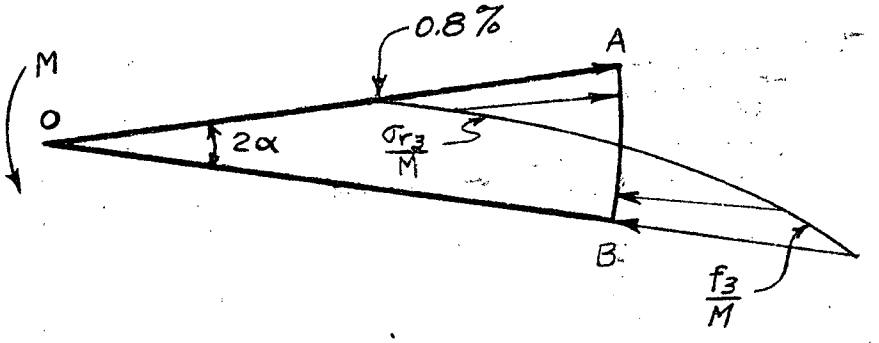

30 WF 116
O
A
B
α = 22.5°
α
r
d = 30"
$\frac{A_f}{A_f + tr\alpha} = 0.358$
R = 72"
2 %
$\frac{\sigma_{r1}}{P_1}$
P_1
2α
3.2 %
$\frac{f_1}{P_1}$
1.5 %
$\frac{\sigma_{r2}}{P_2}$
P_2
8.7 %
$\frac{f_2}{P_2}$
$\frac{\sigma_{r3}}{M}$
1.9 %
M
$\frac{f_3}{M}$



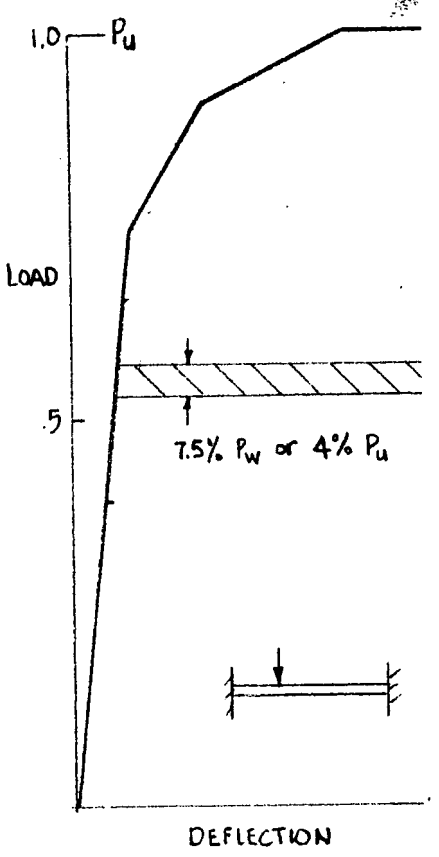
$$\frac{A_f}{A_f + tr\alpha} = 0.492$$



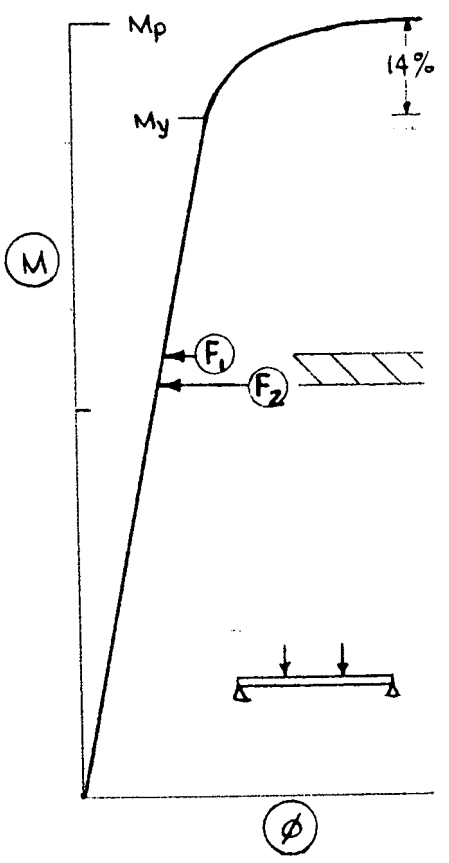




INDETEMINATE STRUCTURE



BEAM

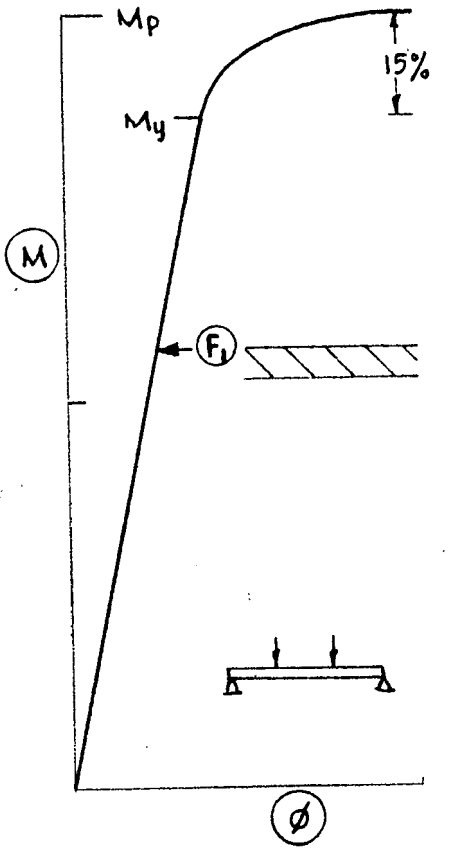


F_1 : $\frac{P_u}{P_w} = 1.75$, $\frac{P_w}{P_u} = .57$

F_2 : $\frac{P_u}{P_w} = 1.88$, $\frac{P_y}{P_w} = 1.65$

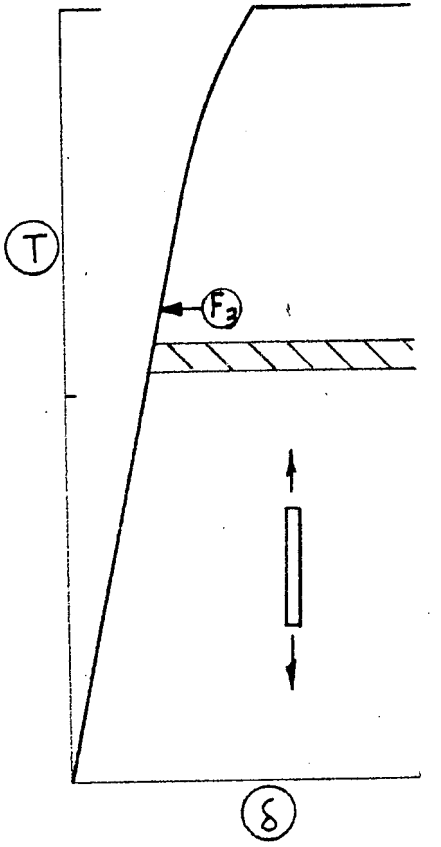
$\frac{P_w}{P_u} = .53$

BRITISH PROCEDURE



F_1 : $\frac{P_u}{P_w} = 1.75$, $\frac{P_y}{P_w} = 1.53$

TENSION



F_3 : $\frac{P_y}{P_w} = 1.65$, $\frac{P_w}{P_y} = .61$

SPECIAL STUDIES

The following special studies are being carried out for course credit by graduate students at the Fritz Laboratory:

Influence of Shear on the Plastic Moment (205B)

To correlate with analysis, a series of tests was performed on WF beams on the influence of shear stresses on the plastic moment. Previous tests tended to confirm the theoretical findings, but a program controlled to study the particular variable was considered desirable. The tests have been completed and a report is being prepared.

Preliminary Study of Deflection Stability (205C)

Little is known about the plastic behavior of structures under variable loading conditions. Certain theoretical considerations indicate that progressive collapse by increasing deflection may occur under a limited number of load applications. Tests on WF beams have been made. The rough draft of the final report is ready for editing.

Biaxially-Loaded Steel Columns (205A)

A set of end fixtures for testing model columns (3/4-in square and under) have been fabricated to permit an exploratory progamm of tests to be carried out on concentrically or eccentrically loaded columns. The end conditions will be controlled so that bending about either or both principal axes will be possible. Acuual testing will begin shortly.

Bolted Connections in Structures Proportioned by Plastic Methods

In order to explore the possibilities of shop welding and field bolting for appreciable moment resistance, a theoretical study will be made and several alternate designs of bolted connections will be tested to determine dependable "hinge moments".

Shearing Modulus in the Plastic Range (241)

Theories of local buckling depend to a large extent on the plastic shearing modulus. Tests to obtain this data were conducted on steel tubes under combined compression and twist. A report is being prepared.

Aging and the Strength of Steel Beams (239)

Tests have been completed in which the specimens were loaded into the plastic region, unloaded, and after aging were deformed to maximum load. Different strain rates and aging times were used to study the influence of these variables on the M-ϕ relationship. A report has been prepared and will be available shortly. Under condition of "uniform moment" strain aging has been shown to have such a small effect that it may be neglected.

Welded Corner Connections in Tension (242)

The corner connections from Portal Frame #3 (12WF36) were removed from the frame and tested with a tensile load across the knee so that the moments developed were opposite those normally experienced in a portal knee. One knee had been subjected to very high moments and rotation during the frame test while the other had not been subjected to moments as high as its

yield moment. No fractures occured during these tension tests. The testing and analysis of results has been completed. A report shall be completed soon.

Box Sections in Plastic Design (247)

The problem of providing lateral support to rolled beams which are to be used in plastic design has been shown to be real and difficult. The Lateral buckling tendency of a section is directly related to its torsional regidity. It is expected therefore that closed box sections should be vastly superior to rolled sections as far as lateral buckling is concerned. The pilot program now under way as a graduate student research project involves the testing of a box beam (14" deep) subjected to a pure plastic moment over a length of 150 inches. The equivalent rolled WF section (14 WF 30) would buckle at strains equal to the yield strain where as the box section is expected to reach at least strain hardening.

FUTURE PLANS
(Tentative)

Practical Applications

Rules of Practice - Supplement
Analysis (Tier Buildings)
Design Examples
Use of Models

Frame Studies

Portal Frame (Gabled roof, combined loading)
Tier Building Frame
Simulated Building Structure (double frame)
Arches

Studies of Components

Connections: Rotation Capacity
Framed Columns
*Haunched Connection
*Built-Up Members

Studies of "Modification" and Special Topics

Inelastic Instability: Stiffening
Repeated Loading (as part of a frame test)
Lateral Bracing
Deflections

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* Pending final Committee action.

WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS

List of Reports

I. Progress Reports, Published or for Publication

1.	Luxion, W. Johnston, B. G.	PLASTIC BEHAVIOR OF WIDE FLANGE BEAMS Welding Journal, 27(11), p. 538-s F.L. #203.3, Reprint No. 63.	Nov. 1948
2.	Beedle, L. S. Ready, J. A. Johnston, B. G.	TESTS OF COLUMN UNDER COMBINED THRUST AND MOMENT, SESA Proceedings, 8(1), p. 109, F.L.#205.2, Reprint No. 72.	Dec. 1950
3.	Yang, C. H. Beedle, L. S. Johnston, B. G.	PLASTIC DESIGN AND THE DEFORMATION OF STRUCTURES, Welding Journal, 30(7), p. 348-s, F.L.#205B.2, Reprint No.75.	July 1951
4.	Topractsoglou,A. Beedle, L. S. Johnston, B. G.	CONNECTIONS FOR WELDED CONTINUOUS PORTAL FRAMES Part I - Test Results and Requirements for Connections, Welding Journal, 30(7), p.359-s Part II - Theoretical Analysis of Straight Knees, Welding Journal, 30(8), p. 397-s Part III - Discussion of Test Results and Conclusions, Welding Journal, 31(11), p. 543-s F.L.#205C.6, Reprint No. 80.	July 1951 Aug. 1951 Nov. 1952
5.	Yang, C. H. Beedle, L. S. Johnston, B. G.	RESIDUAL STRESS AND THE YIELD STRENGTH OF STEEL BEAMS, Welding Journal, 31(4), p. 205-s, F.L. #205B.8, Reprint No.78.	Apr. 1952
6.	Ketter, R. L. Beedle, L. S. Johnston, B. G.	COLUMN STRENGTH UNDER COMBINED BENDING AND THRUST, Welding Journal, 31(12), p. 607-s, F.L. #205A.6, Reprint No.81.	Dec. 1952
7.	Ruzek, J. Knudsen, K. E. Johnston, E. R. Beedle, L. S.	WELDED PORTAL FRAMES TESTED TO COLLAPSE, Proceedings, SESA, 9(1), p. 159 Welding Journal, 33(9), p.469-s (Reprint),F.L. #205D.4, Reprint No.92.	1952 Sept. 1954
-	Beedle, L. S.	RESEARCH ON RIGID FRAMES Proceedings, AISC National Engineering Conference, p. 21, F.L. #205.18	Apr. 1952
8.	Johnston, B. G. Yang, C. H. Beedle, L. S.	AN EVALUATION OF PLASTIC ANALYSIS AS APPLIED TO STRUCTURAL DESIGN, Welding Journal, 32(5), p. 224-s, F.L.#205.14 Reprint No. 87.	May 1953

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